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SIGNIFICANCE OF SELECTED LINEAMENTS IN ALABAMA*

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ABSTRACT

Four lineaments in the Alabama Appalachians that appear on ERTS-1 imagery have been geologically analysed. Two of the lineaments appear to have regional geologic significance, showing relationships to structural and stratigraphic frameworks, water and mineral resources, geophysical anomalies, and seismicity. The other two lineaments are of local geologic significance, but, nevertheless, have important environmental implications.

INTRODUCTION

With the advent of orbital photography, a few geologists have reported hitherto unknown alignments, variously termed, "linears," "lineations," "lineaments," or "linear features" (e.g., Lowman, 1969; Powell and others, 1970; Lathram, 1972). Following the launch of ERTS-1 and with the subsequent acquisition of virtual world-wide coverage, a greatly increased number of workers have reported these features (e.g., Gold and others, 1973; Isachsen and others, 1973). In spite of the many reports, few lineaments have been carefully field checked, consequently their nature and genetic relationship remain largely unknown. In this paper, four selected lineaments in the Alabama Appalachians for which field data have been collected will be discussed. Two of the lineaments are relatively long, extending across the entire state and appear to have regional geologic significance; the other two are shorter and have only local geologic significance. Based on the field data collected in each case, speculations as to the nature of the lineament-causing features will be discussed and the importance of such information to the operations of the Geological Survey of Alabama will be pointed out.

MAJOR LINEAMENT COMPLEXES

The Geological Survey of Alabama first became aware of lineaments through an analysis of Apollo 9 multispectral photographs of east-central Alabama (Powell and others, 1970; Drahovzal and Copeland, 1970; Drahovzal and Neathery, 1972). Two lineaments were exceptionally well displayed on the areally limited Apollo photography. Recent ERTS data have permitted extension of these lineaments into areas of the state where satellite imagery was previously unavailable. Careful study of ERTS imagery at a scale of 1:250,000 has shown that the two lineaments are actually lineament complexes. The complexes are linear zones composed of a series of shorter discontinuous, en echelon lineaments, with an overall trend approximately at right angles to Appalachian structural strike. The individual

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segments occasionally cross one another or bifurcate, but generally are parallel to subparallel. Over the past several years, fairly extensive field data have been collected that show relationships and provide clues to the nature of the two lineaments.

Structural Relationship

Anniston Lineament

The northeastern lineament complex (A-A', fig. 1), herein designated the Anniston lineament (for the city of Anniston, Calhoun County, Alabama), is approximately 290 kilometers long in Alabama. The lineament extends from the vicinity of Riverview on the Chattahoochee River northwestward across the Piedmont province (not show in fig. 1). It crosses the Brevard fault zone (BF, fig. 1) with no apparent disruption and continues northwest to the Little Tallapoosa River where it parallels a short stream segment (not shown in fig. 1). Extensive field studies in this area, however, have not revealed the presence of any major structural features correlative with the Anniston lineament complex. The lineament complex northwest of this area parallels the Tallapoosa River for several kilometers before crossing it at a major gap through a series of moderately high ridges (not shown in fig. 1). Before transecting the metamorphic front (MF), the lineament trace passes along the northeast limit of Talladega Mountain (TM) whose topographic expression is controlled by the underlying quartzites. North of the lineament, the quartzites change to fine-grained meta-arkose with interbedded slate. The lineament crosses the metamorphic front near the northeast side of a left-lateral 10-11 kilometer recess. Just beyond the metamorphic front, the lineament trace transects a prominent quartzite ridge at the point where the ridge abruptly changes strike from north-south to nearly east-west (not shown in fig. 1). The northwest flank of the ridge is bounded by the Jacksonville thrust fault (JF) where the main lineament and a short branch pass along either side of a narrow 5-6 kilometer southeasterly recess on the fault trace (fig. 2). The overridden block contains a small northwesterly elongate fenster (A, fig. 2) and several abruptly terminated, faulted synclines (B, fig. 2) near where the lineament complex passes. To the northwest, the lineament complex crosses just northeast of a 7-kilometer right-lateral displacement in the Pell City thrust fault (PCF, fig. 1) and crosses a narrow zone characterized by block klippen and thin imbricate thrust sheets on the lower plate (C, fig. 2). Much of the complexity of this zone appears to result from the abrupt change in strike near where the lineament complex crosses it. Southeast of the Lookout Mountain syncline (LMS, fig. 1), the main lineament trace is intersected by other traces having slightly different orientations. Near the intersection points, the lineament complex crosses an east-dipping homocline at a point where it is right-laterally offset 5-6 kilometers (D, fig. 2). Farther to the northwest, the Gadsden-Rome fault (GRF, fig. 1) abruptly cuts obliquely to regional structure for 10-11 kilometers, terminating the Lookout Mountain syncline. Just southwest of the lineament trace, the Helena thrust fault (HF) terminates. Northwestward, the lineament crosses Wills Valley anticline (WVA) near a point where its structural style changes from an asymmetrical thrust-faulted fold to the northeast to a more nearly symmetrical anticline to the southwest. The lineament continues northwestward crossing the end of the Murphrees Valley anticline (MVA) and the terminus of the Straight Mountain fault (SMF). The lineament crosses the Sequatchie anticline (SA) with little apparent effect and bisects the sharp bend in the trace of the Cumberland escampment (CE). The southwest-flowing Tennessee River abruptly veers out of the Sequatchie anticlinal structure and flows northwest paralleling the lineament for about 40 kilometers. The lineament extends beyond the state line into Giles County, Tennessee, where its trace coincides with the northwest-southeast structural grain on the southwest flank of the Nashville dome (Wilson, 1949, pl. 1). Charles Wilson (1949, p. 333) has speculated that the grain, expressed by closely spaced sharply asymmetrical minor parallel folds, was the result of vertical movement along a set of northwest-southeast fractures in the basement complex. More recent mapping in Tennessee has revealed low-magnitude normal faulting in the vicinity of and on trend with the lineament (Miller and others, 1966).

Harpersville Lineament

The Harpersville lineament complex (named for the town of Harpersville, Shelby County, Alabama; B-B', fig. 1) crosses the low-rank metamorphic rocks of the Piedmont, and passes near the point where the Brevard fault becomes covered by the Coastal Plain onlap (not shown in fig. 1). If the Towaliga fault to the southeast is part of the Brevard zone and they together make up an Inner Piedmont mega-nappe as suggested by some (e.g., Bentley and Neathery, 1970), then the lineament passes very near to the southern termination of this feature. The lineament crosses within approximately 6 kilometers of the southern terminus of Talladega Mountain (fig. 1). The lineament trace transects the metamorphic front along the southwestern edge of the major recess in the front. Northwestward along the lineament, the Pell City fault block is folded into a series of overturned structures that include rocks younger than those composing the block to the immediate northeast and southwest. These younger rocks suggest downwarping where the lineament crosses the block. The Pell City fault itself splays and becomes less distinct in the vicinity of the Harpersville lineament. The rocks within and just northwest of the Pell City block along the lineament complex exhibit a north-northwest strike orientation rather than the typical northeast strike. In addition, overturned thrust slices occur in this block in contrast with the right-side-up thrust slices to the immediate northeast. Northwestward, the lineament trace crosses the Coosa thrust fault at a point where it is left-laterally offset 3-4 kilometers. On the downthrown side of the Coosa fault in the Coosa synclinorium (COS), the lineament passes through a narrow structural high separating two oppositely plunging synclines (not shown in fig. 1). Farther northwestward, in the Coosa and Cahaba (CAS) synclinoria, the lineament transects several major ridges at points of saddle development. The northeast prong of the complex crosses a synclinal feature on the southeast flank of the Birmingham anticlinorium (BA) at a point of major gap development in the ridge and structural change. At this locality, the Middle Ordovician Chickamauga Limestone has been interpreted as being absent across a narrow zone, although 140-180 meters of the unit are present in the immediate vicinity (Butts, 1910). Detailed field studies have not located the limestone in the narrow zone, but have shown that the dip of overlying and underlying beds is markedly steeper where the lineament crosses the syncline. These dips are more than 80°SE as opposed to 10-15°SE on either side of the zone along strike. It is quite probable that the limestone is completely masked in the area of steep dip by the thick mantle of colluvium. Both prongs of the lineament complex cross the southern terminus of the Blount Mountain syncline (BMS) and the Straight Mountain fault. The lineament cuts across the Birmingham-Murphrees Valley anticlinal complex where a change in structural style occurs. Southwest of the lineament, the Birmingham anticlinorium has a steep to overturned northwest limb that is cut by steep southeast-dipping faults including the Opossum Valley fault (OVF). Northeast of the lineament, however, the Murphrees Valley anticline exhibits a vertical to steeply overturned southeast limb cut by the nearly vertical northwest-dipping Straight Mountain fault. The northeast prong of the complex continues to the northwest where it intersects the Sequatchie anticline, the Warrior Basin (WB), and the Cumberland escarpment. At the present time, no known structural changes are apparent along its trace northwest of the Murphrees Valley anticline, but some gap development appears to correlate. The southwest prong crosses the Sequatchie anticline at the point where local upwarp along the anticlinal axis brings to the surface beds as old as Silurian. The prong crosses the eastern part of the Warrior Basin and becomes indistinct.

The offsets, terminations, and changes in structural style apparent along the two major lineaments may reflect the influence of geofractures that bound basement blocks. Because offsets along individual lineaments are not in the same direction, and because faults and folds terminate rather abruptly or change in style near the lineaments, vertical, rather than horizontal movement of the basement blocks may be the dominant form of displacement. Offsets in opposite directions along the same lineament may be explained by block rotation in the vertical plane. Similar situations have been described by Gwinn (1964, p. 891) in the Central Appalachians but have been attributed to upward shearing, inclined or vertical nonoutcropping faults that connect two glide levels along strike. The changes in the decollement-glide levels of local sole thrusts or higher branching stepped thrusts both across and along strike, may be the result of vertical movement in basement blocks. The foregoing structural studies have had an influence on the Geological Survey's concept of the tectonic framework of the southern Appalachians and are currently influencing geologic mapping programs in the province.

Stratigraphic Relationships

In addition to structural relationships, the two major lineaments appear to coincide with variations in Paleozoic stratigraphy in the southern Appalachians.

A succession that appears to show a strong relationship to the major lineaments is the Middle Ordovician. Over much of the southeastern United States, the Lower Ordovician is separated from the Middle Ordovician by a paleokarst unconformity, and the basal Middle Ordovician locally consists of conglomeratic beds having clasts that range from sand to boulder sizes. In Alabama, this unit is called the Attalla Chert Conglomerate Member of the Chickamauga Limestone. In general, the coarsest and thickest development of the Attalla in Alabama lies adjacent to the two major lineaments (fig. 3). The conglomerate is unknown northeast of the Anniston lineament complex. Immediately southeast of the Anniston lineament complex on Wills Valley anticline and near the termination of the Helena thrust fault, clasts, ranging from 15 to 92 cm in diameter occur in pockets as much as 21 m thick (Drahovzal and Neathery, 1971, p. 11, 185). The conglomerate becomes finer and thinner southwestward ranging in thickness from 1-6 m. Immediately southwest of the Harpersville lineament, at the up-plunge end of Blount Mountain syncline, another locally coarse deposit approximately 13 m thick occurs with chert clasts ranging up to 50 cm (Thomas and Joiner, 1965, p. 13). The thickest and coarsest development of the Attalla immediately adjacent to the major lineaments suggests that the lineament-causing structures are in part responsible for the anomalous occurrences. Differential vertical movement of the individual basement blocks contemporaneous with or prior to deposition may have formed the restrictive pockets, or selective karst development along lineament-related fractures during the Early Ordovician may be responsible for the anomalous distribution.

Similar lineament-related changes in lithologies and thicknesses for Cambrian, upper Middle Ordovician and Mississippian rocks of the Alabama Appalachians are known. The apparent relationships between the two lineaments and Paleozoic depositional cycles suggest that differential movement prior to or contemporaneous with these cycles occurred along lineament-related crustal block boundaries.

Relationship to Water Resources

Results of Apollo 9 studies in Alabama have shown relationships between the occurrence of water resources and lineaments in the Valley and Ridge and Piedmont provinces. High-yield springs and wells show a number of excellent lineament correlations (Powell and others, 1970). In addition, it has been demonstrated that certain surface flow anomalies in eastern Alabama are directly related to the occurrence of lineaments. Detailed low-flow studies made in adjacent subdrainage areas along Talladega Creek in Talladega County, Alabama have shown that there is an abrupt pickup in flow at a point where two lineaments intersect the stream. Pickup at the intersection point increases more than 70 times from a flow of 6.6 x 10^{-4} $m^3/sec/km^2$ to 4.7 x 10^{-2} $m^3/sec/km^2$ (Powell and LaMoreaux, 1971; U. S. Geological Survey, 1972, p. 190-191).

The recent extension of the Anniston lineament into Madison County, Alabama through the use of ERTS-1 data has been significant to the intensive study of the hydrology of limestone terranes presently being carried out by the Geological Survey of Alabama. The region, therefore, provides an excellent test area for determining the nature of relationships between lineaments and the occurrence of ground-water resources in limestone terranes. Preliminary results indicate a striking correlation between high-yield springs and wells and areas of lineament concentration. In the southwestern part of Madison County, where the Anniston lineament complex crosses, data for nearly 80 wells and springs are available (fig. 4). The 4-kilometer-wide zone associated with the Anniston complex encompasses wells whose yields range as high as 0.318 m^3/sec and average nearly 0.032 m^3/sec.

Wells located on either side of the zone exhibit markedly lower yields, averaging only about 0.010 m^3/sec. For the area, yields greater than 0.016 m^3/sec are considered to be anomalously high (George Moravec, oral communication, 1973). Structural data for the area indicate a series of low, undulating folds that trend generally northwest-southeast, subparalleling the lineaments (fig. 5). High well yields only generally correspond to structural lows and are probably influenced more by fracturing in the underlying limestone. Correlation of high-yield wells and springs to the lineaments suggests that the lineaments represent fractures and possibly low-magnitude faults that influence the movement and distribution of ground-water resources. Low variabilities in water-level fluctuation amplitudes for some of the lineament-related wells in Madison County appear to parallel the low-discharge variability noted by Powell and others (1970) for lineament-related limestone springs in the Valley and Ridge province. Low variabilities, uncommon for wells and springs in limestone terranes, suggest special recharge conditions. The plotting of lineaments derived from ERTS-1 and other available imagery is becoming an important part of exploration procedures for ground-water resources at the Geological Survey of Alabama.

Relationship to Mineral Resources

The lineaments show remarkable correlation with many of the hydrothermal mineral deposits of Alabama. The occurrence of barite and lead and zinc sulfides in the Valley and Ridge and barite, gold, manganese, tin, and copper, lead, zinc, arsenic, and iron sulfides in the Piedmont has been related to lineaments drived from Apollo 9 photography (Smith and Drahovzal, 1972). Barite appears to show the closest correlation with about 40 percent of the known prospects coinciding with the two major lineament complexes (fig. 1). The richest barite deposits known in Alabama occur along the Anniston lineament where the main branch changes trend slightly and is intersected by a number of shorter segments. Many of the other barite prospects correlate with shorter, less prominant lineaments.

To further evaluate the apparent mineral-lineament relationship, "B" horizon soil samples were collected at about 300-meter intervals along traverses crossing selected lineaments and analysed for eight metals. Preliminary results have been mixed, however, a number of traverses show anomalously high metal concentrations at the points of intersection with the lineaments. Two geochemical profiles across the Anniston lineament complex show excellent correlation (figs. 6 and 7). One traverse (A, fig. 6) crosses an area in the Piedmont province underlain by garnet schist. Dispite a consistent lithology along the traverse, three metals - lead, zinc, and chromium - show anomalously high concentrations where the traverse intersects the Anniston lineament (A, fig. 7). Chromium concentration reaches 179 ppm, more than 4 times the estimated background of 40 ppm; whereas lead and zinc anomalies are about twice their estimated backgrounds. The other traverse (B, fig. 6), also in the Piedmont, crosses a variety of metamorphic lithologies and exhibits two anomalously high chromium concentrations (B, fig. 7). The higher chromium peak reaches a concentration of

374 ppm, more than 5 times the estimated background for the area, and is related to a branch off of the main trace of the Anniston lineament. The second peak is lower, being only about twice the estimated background, but is, nevertheless, sharp and distinct. It correlates extremely well with the main segment of the Anniston lineament.

On the basis of this work, it appears that the distribution of some potentially important mineral resources is related to the lineament-causing structures. The relationship suggests that these structures may be crustal penetrating fractures that serve as migration channels for mineralized fluids and sites of deposition for certain hydrothermal minerals. Additional studies are currently underway in other parts of the state and especially near lineament intersections where samples will be collected on a grid pattern rather than along single line traverses. The lineament-geochemical sampling approach to exploring for potential mineral resources is becoming an important procedure for the Mineral Resources Division of the Geological Survey of Alabama.

Geophysical Evidence

In addition to the geochemical surveys, several gravity surveys have been conducted in the vicinity of the Anniston lineament complex of northern Alabama. Although regional gravity shows no particular relationship to the lineaments, detailed surveys utilizing approximately 160-meter station spacing exhibit anomalies that are correlative with the linear features. A gravity survey conducted in a Mississippian limestone terrane just southwest of Huntsville in Madison County, Alabama (A, fig. 6) shows a sharp 0.4 milligal negative anomaly at the point where ERTS imagery indicates the presence of the main branch of the Anniston lineament complex (A, fig. 8). Figure 8 shows only a small part of the 13-kilometer profile, but to the southwest the anomaly slowly decreases in intensity for a distance of about 2 kilometers. Beyond that point, gravity readings vary only slightly from the regional gradient. To the northeast, several other smaller, but nevertheless sharp, anomalies are present. These appear to relate very closely to northeastern segments of the Anniston lineament complex. The sharpness of the 0.4 milligal anomaly suggests that it represents either a sharp flexure or a fault downthrown to the southwest. Applying the "half-maximum" rule, the anomaly could originate as much as 1,500 meters below the surface. Depth to basement in the area is unknown, but is estimated to be between 1,500 and 1,900 meters below the surface based on scattered well information. The anomaly, therefore, could reflect offset in the basement complex or possibly in the Cambrian Copper Ridge Dolomite. A structure map contoured on the top of the Devonian Chattanooga Shale in the vicinity of the profile and lineament shows a structural low trending in a subparallel fashion to the lineament trace (fig. 5). Some workers have preferred to interpret the data of figure 5 with a fault that parallels the lineament (Geological Survey of Alabama, open file maps). This flexure or fault may also be responsible for the gravity anomaly. A second gravity survey was run across the Anniston lineament complex in the Cumberland Plateau province (B, fig. 6). A negative anomaly of about 0.17 milligal correlates with the lineament complex (B, fig. 8). If the anomaly represents a fault, it is downthrown to the northeast rather than to the southwest as in previous case. It is possible that the thick Pennsylvanian succession has the effect of masking and thereby reducing the magnitude of the anomaly, but final interpretation awaits detailed analysis and correlation with other recently conducted surveys in the area.

Gravity results to date look most encouraging and suggest that, at least in part, the Anniston lineament is the surface expression of a sharp flexure or fault in the subsurface. Future gravity surveys are being planned along both complexes and magnetic surveys will be conducted in association where possible. Some preliminary ground magnetic surveys seem most encouraging but await confirmation before being reported in detail. Detailed ground geophysical surveys appear to be extremely important in evaluating the nature of the lineament-causing structures.

Relationship to Seismicity

Between 1886 and 1971, 14 earthquake epicenters have been reported in Alabama (Eppley, 1965; Woollard, 1968; U. S. Department of Commerce, 1971; G. A. Bollinger, written communications, 1971-1973). Although the earthquakes are rather infrequent and of relatively low intensities (between I and VIII on the Modified Mercalli Intensity Scale of 1931), they may be highly significant to the understanding of the nature of the two major lineament complexes. Those epicenters occurring in the northeastern quarter of the state are shown in figure 1. Four of the epicenters lie directly on the main branches of the Anniston lineament complex and two on the main segment of the Harpersville lineament complex. Coincidence of epicenters with the major lineament traces not only implies that the lineaments are related to basement structures, but also indicates that they may represent structures that are currently active. Microseismic studies are planned as part of proposed ERTS-B research.

TWO MINOR LINEAMENTS

In addition to the two major lineaments, there are a myriad of other lineaments for which very little or no field information is available. The latter are presently considered to be of lesser geologic significance and are classified herein as minor lineaments. There are, however, two minor lineaments for which fairly extensive field data are available.

Wesobulga Creek Lineament

As part of routine geologic investigations and ERTS-1 research, lineament analyses and a ground investigation were conducted in a 420 km^2 area of the northern Alabama Piedmont. Lineament locations and orientations were derived from ERTS-1 and side-looking airborne radar (SLAR) imagery supplemented with low-altitude conventional photographs. Two hundred-forty-two tonal and topographic lineaments were transferred from the various images and plotted on 7½-minute topographic maps for field checking. In the course of the field investigation, more than 2,500 stations were established for which structural data including the orientation of cleavages, foliations, joints, faults, and folds were recorded. The relationships of most of the structural data to lineament traces is inconclusive, although a rough correlation appears to exist between joint orientations (273 stations) and the lineament orientations (fig. 9). Correlation is somewhat better than one might at first believe because compilation of the lineament data on a SLAR base has imparted as much as a 10-degree north-bias due to variable distortion of the SLAR imagery.

A detailed search was made over approximately 195 km^2 of the study area for surface manifestations of any of the image-derived lineaments. A small normal fault that is exposed in a road cut (fig. 10) was discovered and found to coincide with the trace of a lineament expressed both on ERTS-1 and SLAR imagery. The lineament, herein referred to as the Wesobulga Creek lineament, is approximately 4 kilometers in length on SLAR imagery and corresponds with an ERTS lineament about 15 kilometers in length. On both SLAR and ERTS data, orientation of the lineament averages N45°W. The Wesobulga lineament is no more prominant than many other such features for which no structural evidence exists.

The corresponding Wesobulga Creek fault zone is approximately 3 meters wide and has an approximate strike of N40-45°W with displacement of 3-15 meters in the roadcut. The principal zone of movement occurs on the east end of the fault zone where a mylonite-phyllonite zone 10 cm wide marks the fault. The remaining 2.9 meters of the zone is composed of a series of closely spaced vertical shear joints that decrease in number to the west end. To fully investigate the orientation and extent of the fault, eight trenches were dug across its projected trace (fig. 11). Six of the eight trenches nearest to the road exposure cut the fault. One trench located approximately 700 meters north of the road failed to intersect the fault trace (not shown in fig. 11). The trenches show that the fault zone narrows in both directions from the 3-meter-wide zone at the road cut to a half-meter-wide kink band in trench TN-4 and to a disturbed zone less than 2 meters wide in trench TS-3. The trend of the fault, as exposed, coincides with the orientation of the lineament derived from both SLAR and ERTS data. The general shape of the fault zone and its topographic position along the flank of a steep-sided valley suggest that the feature may not be tectonic, but may represent a recent rotational shear related to slumping. Radiogenic age dates (K/Ar) are currently being determined on the mylonitic rock of the principal fault zone. Approximately 500 meters east of the fault, on the adjacent valley wall, another small fault and drag fold are exposed in a road cut, but the relationship of this feature to the Wesobulga Creek fault is unknown at this time.

This example of a positive relationship of one of the ERTS-derived lineaments to a small fault is noteworthy, but certainly not statistically significant. It is not to be regarded as indicating that all or even most lineaments are related to faulting. On the contrary, evidence based on this test area suggests that most of the minor lineaments are not related to obvious structural features. More detailed work is required to determine the significance, if any, of the many other lineaments to the structure of the area.

Kelly Creek Lineament

The other minor lineament for which considerable field data exists was originally discovered on Apollo 9 photography (Powell and others, 1970). Follow-up studies utilizing SLAR and ERTS-1 data have added to our understanding of the feature. The lineament also appears on U-2 photography and conventional panchromatic photo mosaics. Low-level aerial reconnaissance has revealed erosion-deepened hollows and gaps along the lineament, as well as linear regions characterized by trees whose foliage appeared to be slightly darker green than those of the surrounding area (Bailey, 1970). The lineament strikes about N49°W and has been traced for 8 kilometers on SLAR imagery, but appears on ERTS-1 imagery to be part of a somewhat longer linear feature.

The lineament has been the subject of extensive study because it strikes along the axis of Logan Martin dam on the Coosa River (fig. 12). Since impoundment in 1964, leakage from the reservoir has occurred beneath and to the sides of the dam through the highly weathered and fractured limestones and dolostones that underlie the area. Flows of up to 20 m^3/sec have been measured below the dam and during one 2-year period total leakage increased, though it has now stablized (Alverson, 1969). Structural, hydrologic, subsurface, and seismic data show that the lineament represents a deeply weathered fracture zone. Vertical joints coincident and parallel with the lineament were measured at several locations northeast of the dam (Spigner, 1969). The existence of hydraulic connection through solution-widened fractures developed along the lineament has been demonstrated by the following: 1) dye injected into well 262 was detected in well 222 within 24 hours (fig. 12); 2) well 238 has an anomalously high specific capacity of such a magnitude that it must be connected to the reservoir; 3) the lowering of water in a cofferdam on the west side of the river resulted in the lowering of water levels in two wells along the lineament on the east bank (not shown in fig. 12); and 4) sizable increases in surface flow have been noted during low-flow periods where the lineament crosses Kelly Creek just northwest of the dam (Alverson, 1970; Powell and LaMoreaux, 1971). Test drilling west of the dam on the lineament trace encountered nearly 200 meters of highly fractured rock before solid bedrock was encountered. Holes not on the lineament penetrated solid rock at much shallower depths. Several seismic and resistivity profiles confirm the presence of the fracture zone in the areas that correspond to the trace of the lineament (W. L. Scarbrough, oral communication, 1973).

The Kelly Creek lineament, in part at least, most certainly represents a fracture zone. At the present time, it is not known whether this fracture is a fault, but it is contributing to reservoir leakage.

CONCLUSIONS

The major lineaments such as the Anniston and Harpersville lineament complexes are probably related to basement structures. Because the structural offsets and changes do not necessarily parallel the lineament traces and because the lineaments may affect all parts of the Paleozoic succession, the lineaments appear to represent basement geofractures, which have been vertically active throughout much of geologic time. The geofractures may be partly responsible for the present geologic configurations of the Appalachians because of their direct tectonic effect at the time of deformation and their earlier tectonic control of sedimentation. Coincidence of high-yield wells and springs, hydrothermal mineral deposits, geochemical highs and geophysical anomalies with the major lineaments suggests that fracturing of the basement is also expressed in the Paleozoic cover. Seismic activity along the same lineaments indicates that they are related to basement geofractures that are still active.

The evidence relating to these lineaments leads us to speculate about their significance to the tectonic framework of the Appalachians. It is possible that much of the driving force for the thin-skinned tectonics of the Appalachians was derived from primary vertical movement in the basement. The vertical uplift and the attendant development of tectonically unstable conditions in the overlying Paleozoic cover may have resulted in horizontal forces that expressed themselves in the formation of decollement-glide planes in the incompetent units of the Valley and Ridge synclinorium. Such a concept combines parts of both "thin-skinned" and "thick-skinned" ideas which have been expressed before (e.g., Cloos, 1948; Boos and Boos, 1957; and Eardley, 1963), but generally not for the Appalachians.

The northwest orientation of the major lineaments in Alabama is closely similar to the trend of the postulated Bahama fracture zone off the southeast coast of North America (LePichon and Fox, 1971). This and other fracture zones along and seaward of the present coast of North America are thought to be genetically related to the open ocean fractures lying perpendicular to the Mid-Atlantic ridge and to complimentary marginal fracture zones along the African coast. Some of the marginal fracture zones are known to be related to basement ridges farther onto the continent, such as the Cape Fear fracture zone that is aligned with the axis of the Cape Fear arch. The similarity in orientation between the major lineaments in Alabama and the Bahama fracture zóne may represent an analogous relationship. This concept is consistent with J. T. Wilson's (1965) suggestion that the pre-rift continental mass was broken by faults or ancient lines of weakness that after rifting and rotation, represent less tectonically active continental equivalents of active Mid-Atlantic transform faults.

The minor lineaments are believed at the present time to have limited geologic significance. The two discussed--the Wesobulga Creek and Kelly Creek lineaments--have demonstrated local geologic and environmental importance. Most of the minor lineaments, however, seem to have little or no obvious relationship to the local geology, but detailed information is lacking in most areas.

A great deal of field data and analysis will be required to determine the genetic nature and significance of the lineaments. It is hoped that this paper has presented a beginning in that direction. The ERTS-1 program in some respects has not saved the geologist field time and expense, as may be validly claimed for some problems, but it has sharpened his sensitivity to certain aspects of regional geology that may be highly significant to a fuller understanding of geologic relationships and environmental perspectives.

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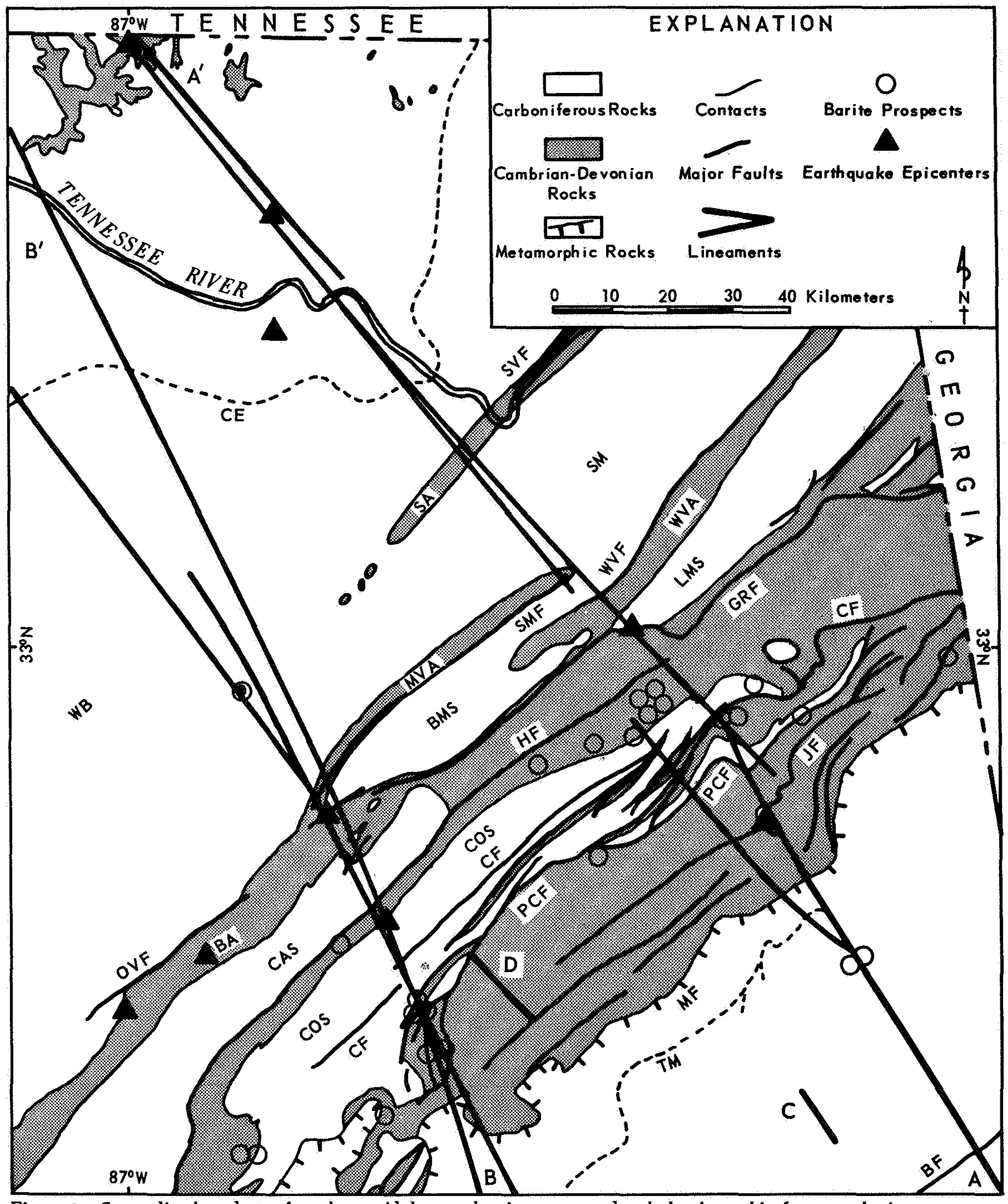

Figure 1.—Generalized geology of northeast Alabama, showing structural and physiographic features, barite prospects, earthquake epicenters and lineaments (A-A'—Anniston, B-B'—Harpersville, C—Wesobulga Creek and D—Kelly Creek). BA—Birmingham anticlinorium, BMS—Blount Mountain syncline, BF—Brevard fault, CAS—Cahaba syncline, CE—Cumberland escarpment, CF—Coosa fault, COS—Coosa synclinorium, GRF—Gadsden-Rome fault, HF—Helena fault, JF—Jacksonville fault, LMS—Lookout Mountain syncline, MF—metamorphic front, MVA—Murphrees Valley anticline, OVF—Opossum Valley fault, PCF—Pell City fault, SA—Sequatchie anticline, SM—Sand Mountain, SMF—Straight Mountain fault, SVF—Sequatchie Valley fault, TM—Talladega Mountain, WB—Warrior basin, WVA—Wills Valley anticline, WVF—Wills Valley fault. Geology modified from Adams and others, 1926.

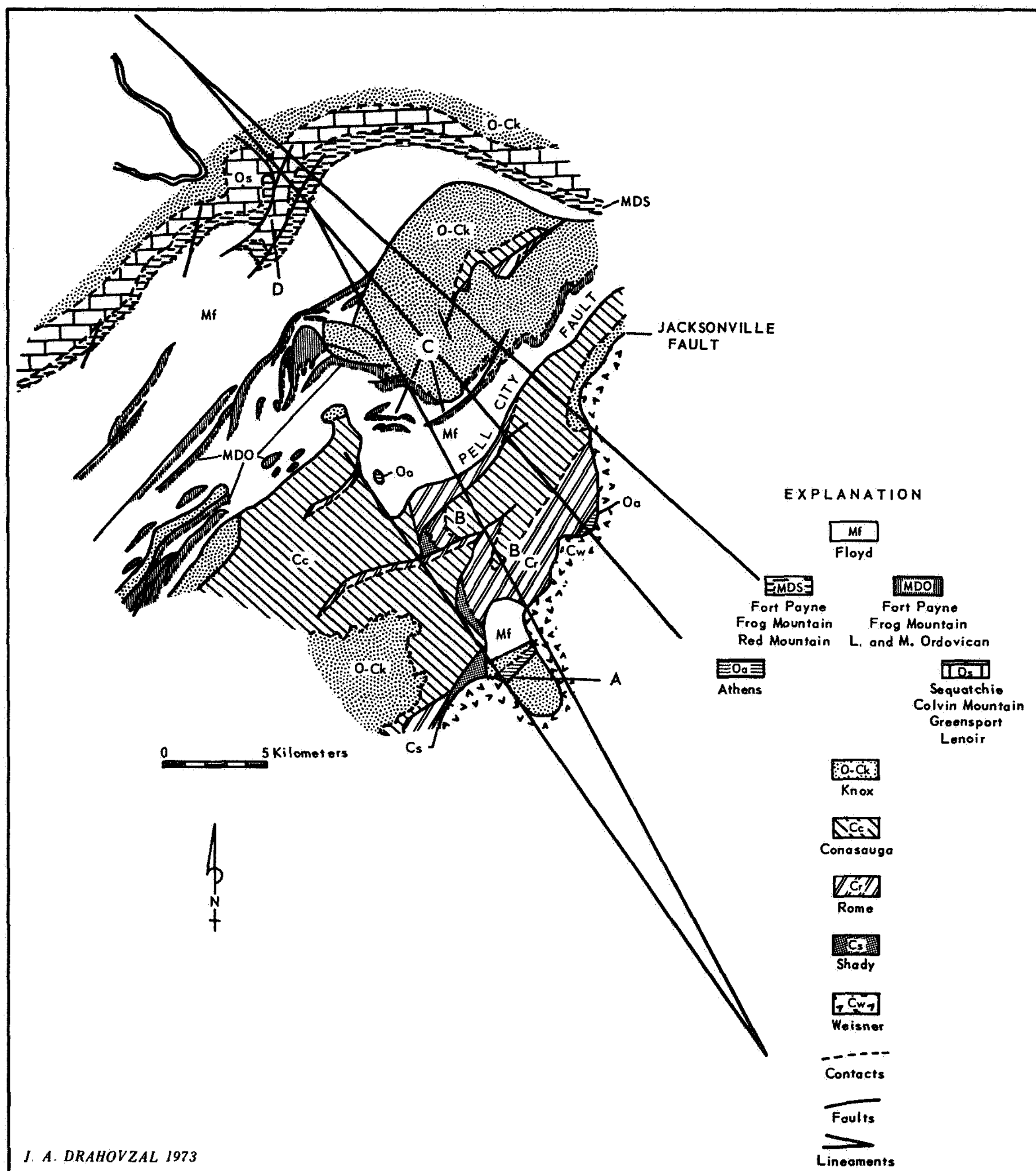

Figure 2.—Generalized geology of the Anniston Gadsden area, Alabama showing its relationship to the Anniston lineament complex. Geology modified from unpublished field maps of T. L. Neathery (1968) W. A. Thomas and J. A. Drahovzal (1969-1970) and J. A. Drahovzal (1971-1973).

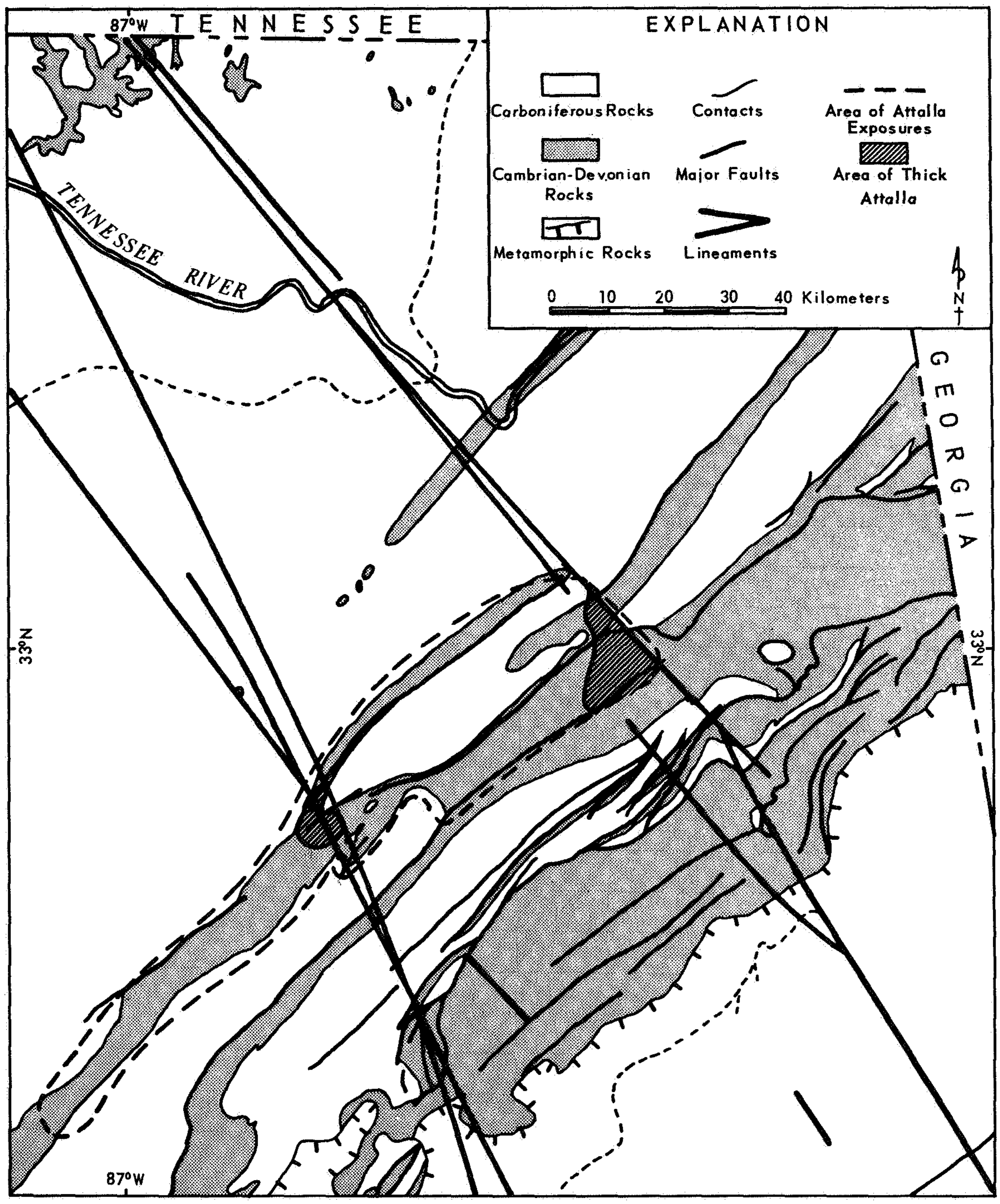

Figure 3.—Generalized geology of northeastern Alabama showing the approximate limits of the Attalla Chert Conglomerate Member of the Chickamauga Limestone and the areas of thick and coarse development. Data modified from Butts (1910), Thomas and Joiner (1965), and Drahovzal and Neathery, (1971).

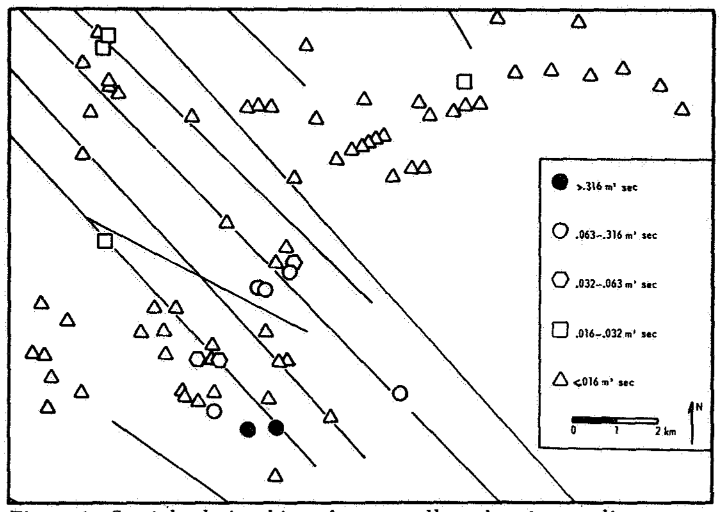

Figure 4.–Spatial relationships of water wells and springs to lineaments associated with the Anniston lineament complex in southwestern Madison County, Alabama. See figure 6 for location.

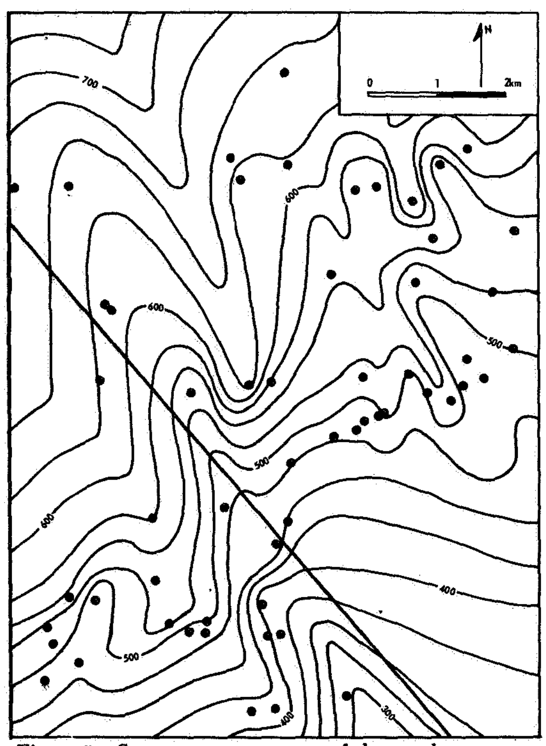

Figure 5.–Structure contour map of the southwestern part of Madison County, Alabama, showing the trace of the Anniston lineament. Contour interval is 25 feet and is drawn on the top of the Chattanooga Shale. Dots represent well locations.

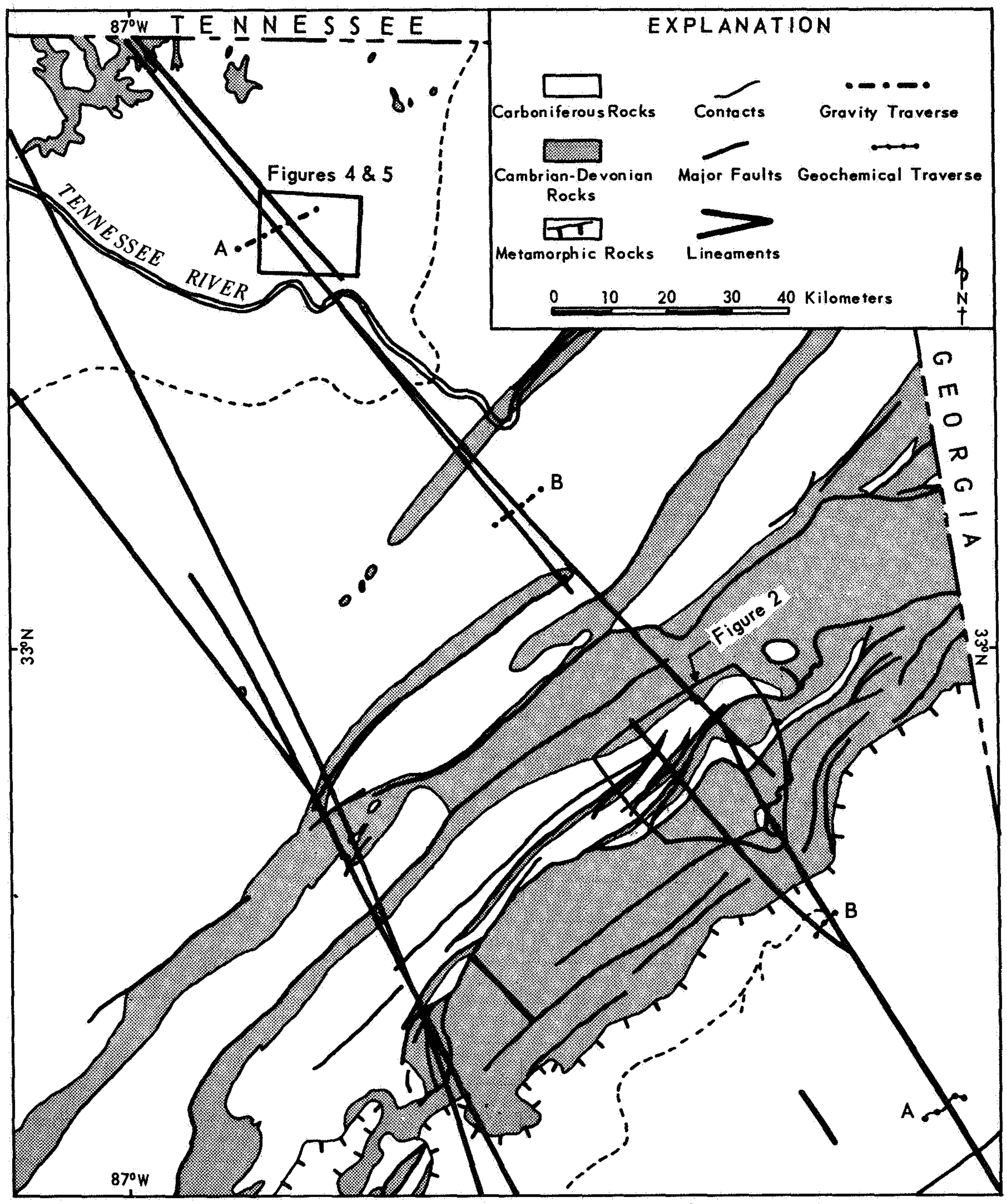

Figure 6.—Locations of geochemical and gravity profiles across the Anniston lineament complex and locations of figures 2, 4, and 5.

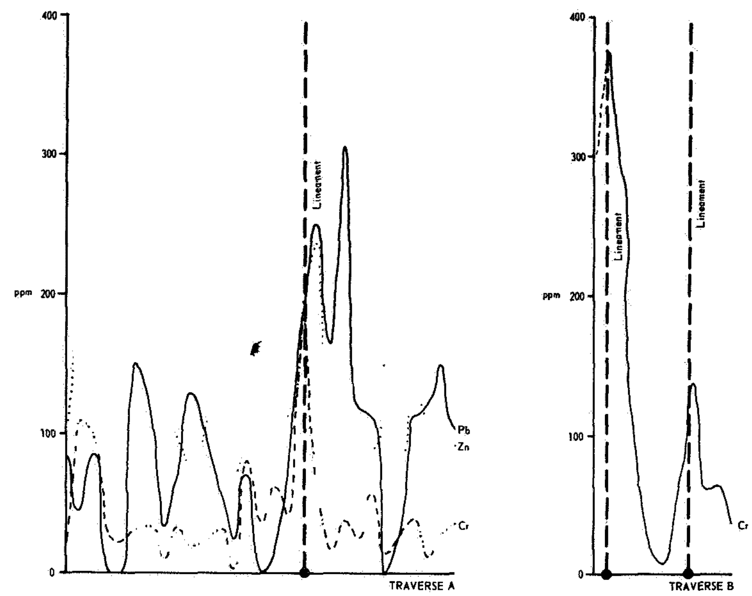

Figure 7.—Geochemical profiles across the Anniston lineament complex. See figure 6 for locations. From unpublished field and laboratory data (W. E. Smith, J. A. Drahovzal, and N. A. Lloyd, 1972).

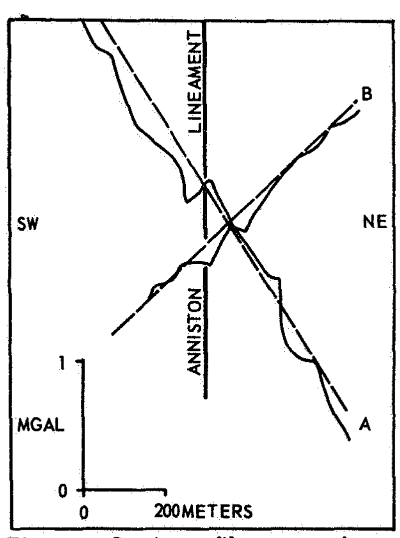

Figure 8.—Gravity profiles across the Anniston lineament complex. See figure 6 for locations. Dashed lines represent interpreted regional gravity; solid lines gravity anomalies. From unpublished field data collected by G. V. Wilson (1973).

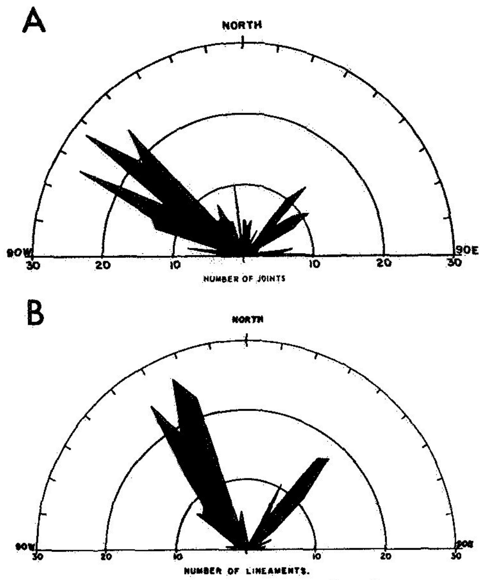

Figure 9.—Rose diagrams comparing the orientations of lineaments to joints in the vicinity of the Wesobulga Creek lineament.

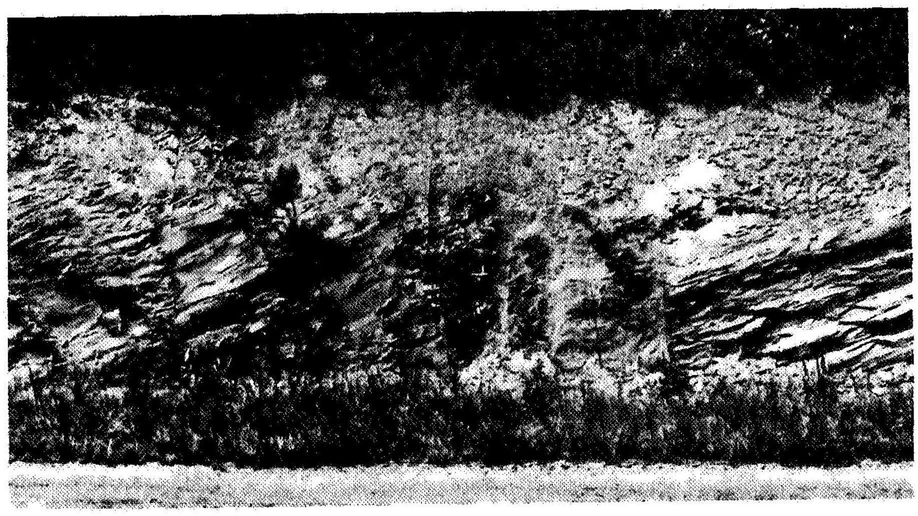

Figure 10.—Road cut exposing a normal fault that coincides with Wesobulga Creek lineament. Fault is 3 meters in width and downthrown to the right.

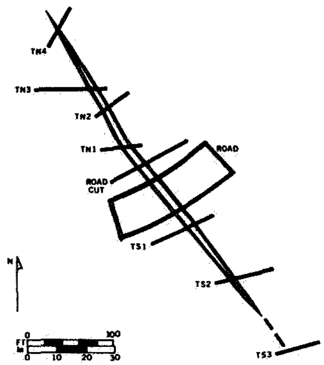

Figure 11.—Map showing the fault trace, road cut and trenches associated with the Wesobulga Creek lineament.

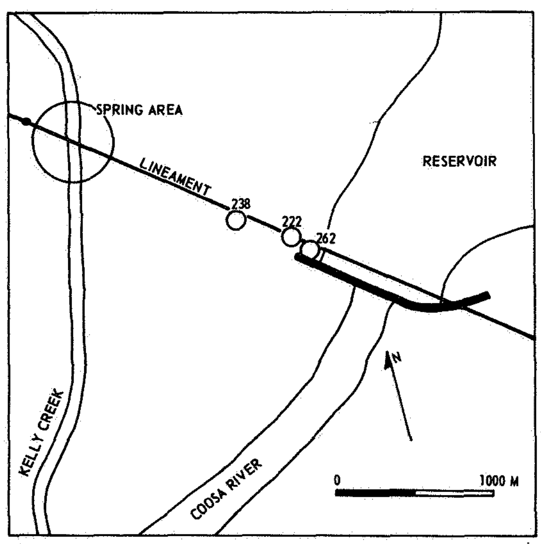

Figure 12.—Kelly Creek lineament in the vicinity of Logan-Martin Dam (modified from Alverson, 1970).